HIGHLY OBLIQUE BISTATIC RADAR OBSERVATIONS USING MARS GLOBAL SURVEYOR.

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Introduction: Since the beginning of Mapping, Mars Global Surveyor (MGS) has collected data from over 10000 radio occultations -- more than half accompanied by transient surface echoes. These echoes arise when the spacecraft high-gain antenna (HGA) incidentally illuminates parts of the surface near the occulting limb. When the direct raypath is well separated from the limb, no microwave energy falls on the surface and no echoes are observed. The HGA beamwidth is 1.6 deg, so the majority of echo energy results from illumination at incidence angles ϕ>89 deg, well beyond the regime for which traditional quasi-specular scattering models are valid and making geophysical interpretation difficult. The work to date has focused on characterizing the reflected signals to identify patterns and detect systematic biases.

Geometry: In conventional quasi-specular bistatic scattering experiments, the spacecraft antenna is aimed toward the point on the mean planetary surface expected to give mirror-like reflections; the echo signal is captured by receiving facilities on Earth [1, 2]. During Mars Global Surveyor (MGS) radio occultations the antenna, which has a half-power full beamwidth of only about 1.6 deg, is pointed in the Earth direction throughout. Surface scattering can be observed for only a few seconds, when the beam is simultaneously illuminating both the atmosphere and surface. Incidence angles on the surface during these times are extreme (greater than 89 deg from vertical).

Observations: Surface echoes have been seen in several thousand MGS occultations; methods have been developed for autotracking Doppler drift and for estimating echo amplitudes and have been applied to data collected in 1999. Autotracking fails when echo strengths are weak -- frequently the case at large Earth-Mars range, but also occurring occasionally near opposition when the reflecting surface is apparently very rough. As a rule of thumb, echo strengths are four orders of magnitude below the strength of the directly propagating carrier, but variations of a factor of ten either stronger or weaker are not uncommon.

Small deflections of the spacecraft antenna either toward or away from the surface can have significant impacts on the echo signal reaching Earth. Attempts at correlating variations in echo amplitude with HGA pointing have been only partially successful; the absolute pointing reconstruction accuracy is only about 0.2 deg whereas 0.1 deg is needed for comparison with data. Nonetheless, repeatability of measurements when the reflecting region is similar on nearby orbits is evidence that the HGA is stable over time scales of days. We have also detected changes in echo strength which correlate with changes in HGA pointing strategy -- such as before and after the first HGA azimuth anomaly early in the mission. This provides confidence that relative measurements of echo power over a few days to weeks are useful even though the absolute power may be uncertain.

Spatial Patterns: We searched the 1999 data for sets of especially strong echoes arising from small regions on the surface. The typical echo footprint is only 50x50 km, meaning that overlapping coverage is very rare even after thousands of experiments. Because of MGS orbit evolution, occultations in the northern hemisphere during the first Mars year were spread over a wide range of latitudes. But occultations in the south were concentrated in a latitude band near 65-75S. We found that 15-30 occultation points fell within each 10 deg interval of southern hemisphere longitude.

Most of the echoes from (65-75S, 260-270E) had amplitudes less than 30 dB below the carrier -- a factor of 10 stronger than neighboring regions. This area does not stand out as unusual in images or in MOLA topography; but its favorable reflecting properties for radio waves may be controlled by structure at centimeter scales, not detectable by other instruments. Additional data from 2001 and 2003 may be useful in confirming the signal patterns and eventually allowing interpretation of these unusually strong echoes.

References: [1] Simpson, R. A. (1993) *IEEE Trans. Geosci. Remote Sens*., *31*, 465-482. [2] Simpson, R.A., and G.L. Tyler (2001) *Icarus*, *152*, 70-74.